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# ANALYSIS OF INTERCONNECTION BETWEEN PHYSICAL AND PROTECTIVE PROPERTIES OF TWO-COMPONENT EPOXY PRIMER

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This paper presents the research into protective properties of two-component epoxy primer obtained by measurements of the notch corrosion and by testing of the gloss as a physical property. In order to obtain different values of measured response, the first experiment was done by applying the primer in various amounts of the dry film thickness, while the second experiment was based on combining various contents of anti-corrosion pigment. Analysis of the obtained research results proved the interconnection between the two observed properties. It was confirmed that the obtained results were inversely proportional for both experiments. Protective properties of coating could be assessed by measuring the gloss value, which is simpler and faster than measuring the notch corrosion.

*Key words*: coating, two-component epoxy primer, gloss, notch corrosion, properties

## INTRODUCTION

During their service life, construction materials usually decay because of corrosion mechanisms [1]. Such damages and their consequences require serious consideration, as pointed out by NACE International in their publication stating that costs caused by corrosion amounted to 3,4 % of global GDP. Analysis of previously conducted studies referring to issues of corrosion damage in agricultural, industrial and service provision sectors in India, USA, Japan, Kuwait and the United Kingdom showed that appropriate surface protection of materials could reduce costs connected to corrosion damage by 15 to 35 % [2]. By following such fact, anticorrosion protection can be secured in three different ways, such as to modify internal factors of damage by changing the chemical composition or the structure of materials, to modify external factors of damage, or to prevent direct contact of reactants from environment with structures or elements that shall be protected from corrosion [3]. The latter refers to protection of materials with organic coatings. When developing such coatings, it is necessary to achieve optimal corrosion resistance for defined service conditions. This can be determined by measuring the notch corrosion in order to estimate coating decay. Testing of such protective property of the applied coating is time consuming, i.e. it lasts quite long to obtain results necessary for coating classification. This research aims to determine if it is possible to connect coating's protective property with its physical property, and to determine if the coating's resistance to corrosion can be estimated on the basis of values that are obtained by simpler and faster testing, such as measuring of the coating gloss.

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## EXPERIMENTAL PART

The experiment started with definition of the input parameters, which variation of values leads to changes in the observed protective property (assessment of coating decay), and physical property (gloss). The research was performed on a two-component epoxy primer, and measurements of the protective effect and the gloss were performed in two experiment runs. The first run involved the variation of the coating dry film thickness, and the second run referred to variation of the anti-corrosive pigment portion.

Coating dry film thickness refers to the size of the barrier between the protected material and the aggressive environment. Its variation results in changes of the observed properties, and such changes can be interrelated. The values of the coating dry film thickness can range from 60 ± 6 μm [4] up to 190 μm [5], which usually depend on coating chemical composition and its properties. Manufacturer of the two-component epoxy primer used in this experiment determines optimal coating thickness as of 120 μm. Other two values were selected accordingly, the lower value being 80 μm, and the higher value being 160 μm. Since it is technically impossible to apply the coating in the exact value of 120 μm, the interval from 115 to 125 μm was defined as acceptable. After 15 measurements of the coating dry film thickness, the mean value of the dry film thickness per each specimen had to be within the set boundaries. Accordingly, two other intervals were defined, i.e. the interval from 75 to 85 µm was defined for the required 80 µm, while the interval from 155 to 165 µm was defined for 160 µm. The second experiment run was focused on variations of the anti-corrosive pigment portion, since it is the most important parameter for improvement of coating resistance to corrosion. The protective effect of the coating depends on creation of chemical compounds between the protected material and the applied coating. If there is mechanical damage at the coating layer, its protective barrier is deteriorated, yet the anti-corrosive pigments will assure sufficient protective action. Values of anti-corrosive pigment in the previously conducted studies ranged from 2,6 % [6] up to 30 % [7]. The values referring to variations of the anti-corrosive pigment in this experiment were 0 % (without pigment), 6 % and 12 %.

Surface of the specimens was prepared according to the HRN EN ISO 12944-4 standard, with the requested quality of Sa 2,5 as of the HRN ISO EN 8501-1 standard. Prepared surfaces of specimens were visually inspected and their roughness was measured in order to make sure that the surface roughness was in range from 40 - 70 µm. The coating was then applied by airless spraying. After the coating application, specimens were placed in a salt spray chamber, which is used for accelerated laboratory testing. The specimens were cyclically sprayed with sodium chloride solution for 240 hours. Concentration of the sodium chloride solution and other experiment parameters, are determined by HRN EN ISO 9227 standard, as overviewed in the Table 1.

Measurement of physical property referring to the coating gloss was done according to HRN EN ISO 2813 standard, which classifies the gloss as high gloss, gloss, semi-gloss, semi-matte, matte and deep matte. Due to different classifications of the gloss values, there were different geometries applied in measurement, such as geometry 20°, 60° and 85°. Measuring of the gloss at an angle of 60° covers the gloss measurement area ranging from 10 to 70 %. The gloss area less than 10 % is measured at an angle of 85°, while the gloss area larger than 70 % is measured at an angle of 20°. The Figure 1 shows a gloss meter used to measure gloss on the specimens.

Table 1 **Parameters for testing of specimens in salt spray chamber [3]**

| Parameters for testing of specimens in salt spray chamber | HRN EN ISO 9227 |
|---|---|
| temperature of testing environment / °C | 35 ± 2 |
| solution | NaCl |
| Concentration of NaCl solution / % | 5 |
| pH value of the condensate at 25 ± 2 °C | 6,5 - 7,2 |

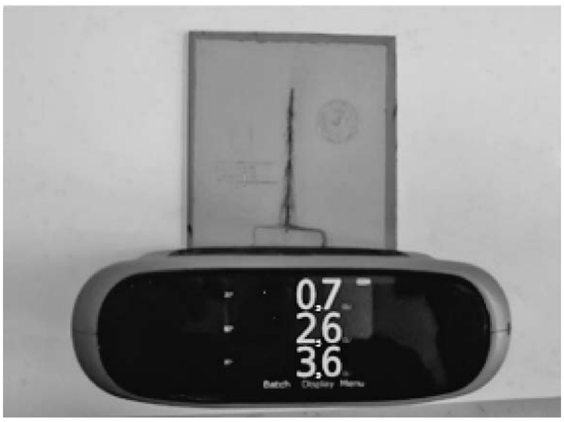


**Figure 1** Gloss meter

Analysis of changes in the measured values of the gloss provided an insight into degradation of chemical bonds within the coating. Decreased values of the gloss indicate greater degradation of components caused by chemical mechanisms. The primer used in this experiment is not characterized by a high value of gloss, i.e. its gloss is within 10 %. The gloss meter provided values for all geometries, yet the characteristics of the tested coating requested the application of the value obtained with the geometry 85°, as the last showed one. Assessment of coating decay was carried out in accordance with HRN EN ISO 4628-8 standard. Unlike measurements of the coating gloss, which refer to the physical property, testing of notch corrosion refers to examination of the coating protective property. The tests were performed to evaluate the coating resistance to corrosion mechanisms in certain service conditions by removing the coating around the notch on specimens, and by identifying the spots that developed corrosion. The size of corrosion spreading on the product was measured at six points around the notch. Measuring procedure is presented on the Figure 2. During measurement,

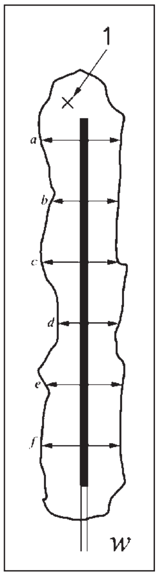


**Figure 2** Measuring of corrosion product on specimen [8]

it was necessary to pay attention to mutual distance between focal points of corrosion mechanisms, which should be at least 6 mm. In order to make the measurements as accurate as possible, Digimizer software was used to perform the measurements. The obtained data were entered into formulas 1 and 2 in order to obtain the value that determines the protective effect [8]:

$$d_1 = \frac{a+b+c+d+e+f}{6} \quad (1)$$

$$d = \frac{d_1 - w}{2} \quad (2)$$

The output values of all performed measurements were determined by three repetitions, and the arithmetic mean of all measured values was applied as the measurement result. The Table 2 overviews results of performed measurements for varied values of the anti-corrosive pigment content. The Figure 3 shows results referring to different input variable effects on the value of gloss, while the Figure 4 shows the same effect on the protective properties of the coating.

Table 2 **Results of varied values of the anti-corrosive pigment content**

| Specimen | Anti-corrosive pigment content / % | Gloss 85° / GU | Notch corrosion / mm |
|---|---|---|---|
| 1 | 0 | 3,6 | 0,23 |
| 2 | 6 | 3,9 | 0,19 |
| 3 | 12 | 4,5 | 0,1 |

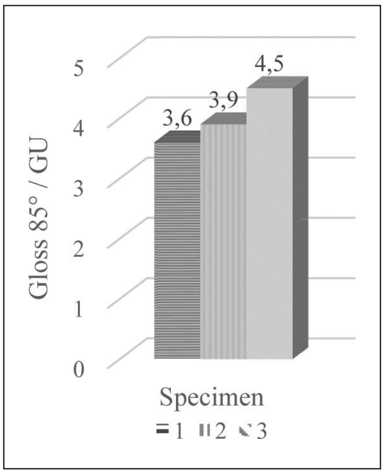


**Figure 3** Graphic presentation showing the effects of anti-corrosive pigment content on the gloss

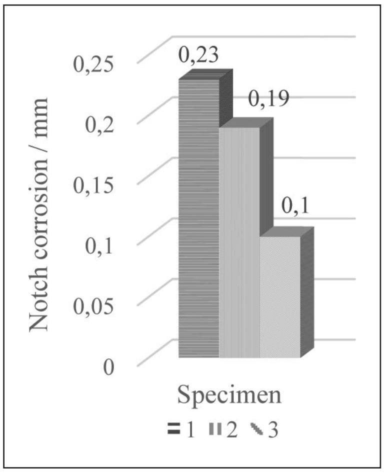


**Figure 4** Graphic presentation showing the effects of anti-corrosive pigment content on protective properties of coating

The above-presented graphs prove that the increase in the content of anti-corrosive pigment caused the increase in the measured values of the coating gloss and the decrease in the notch corrosion value. It can be concluded that the obtained results were inversely proportional.

The Table 3 presents the results obtained within measurements of varied values of the dry film thickness. The Figure 5 graphically presents the results referring to effects of varied values of the input variable on the gloss, while the Figure 6 shows the same effect on the protective properties.

The above-presented graphs also prove that the increase in the content of anti-corrosive pigment causes an increase in the measured values of the coating gloss and inversely proportional decrease in the value of

Table 3 **Results of varied values of the dry film thickness**

| Specimen | Coating thickness /μm | Gloss 85° / GU | Notch corrosion / mm |
|---|---|---|---|
| 4 | 75 - 85 | 2,7 | 0,22 |
| 5 | 115 - 125 | 3,9 | 0,19 |
| 6 | 155 - 165 | 4,8 | 0,15 |

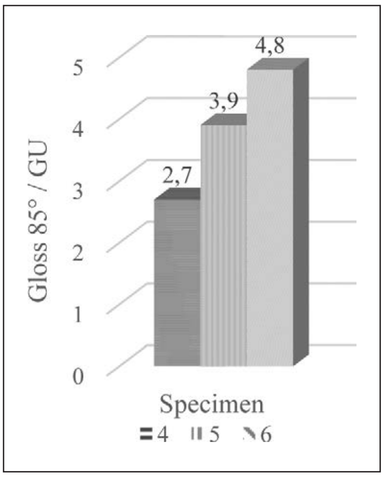


**Figure 5** Graphic presentation showing the effects of the dry film thickness on the gloss

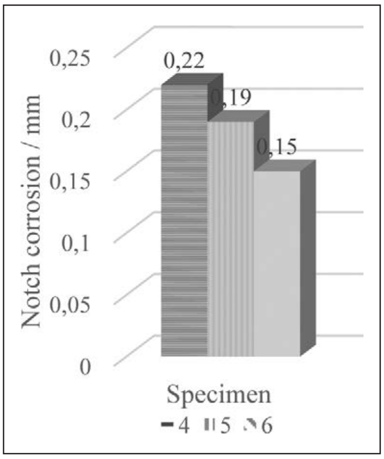


**Figure 6** Graphic presentation showing the effects of the dry film thickness on the notch corrosion

notch corrosion. By matching it with the previously described experiment run, the results were also inversely proportional.

## CONCLUSION

Obtained research results lead to conclusion that the coating resistance to corrosion can be also defined by measuring the coating gloss, which is one of the physical properties of coating. Comparison between the results of gloss and notch corrosion measurements proved that they are inversely proportional. The gloss value is the highest in specimens with higher anti-corrosive pigment content, while the notch corrosion is the lowest for the same specimens. The same occurs with the increase of the dry film thickness, in the case of which the gloss value increases and the notch corrosion decreases. This leads to the conclusion that the decrease in the coating gloss value indicates some chemical changes in the applied coating, which cause its deterioration and reduce its protective effect, thus leading consequently to the increased development of corrosion mechanisms.

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**Note:** The responsible person for English translation is prof. Martina Šuto, University of Osijek